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New Zealand marine biosecurity: delivering outcomes in a fluid environment

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Abstract Marine biosecurity, the protection of the marine environment from impacts of non-indigenous species, has a high profile in New Zealand largely associated with a dependence on shipping. The Ministry of Fisheries is the lead agency for marine biosecurity and is tasked with managing the risks posed by pests and non-indigenous marine species. Much like the terrestrial environment, multiple pathways provide ample opportunities for new species to arrive. The Marine Biosecurity Team was established in 1998, and under the Biodiversity package delivered by government, has undertaken an ambitious programme to deliver biosecurity outcomes by reducing the knowledge gaps and establishing management frameworks. A Risk Management Framework aids decision-making and operational planning. Despite significant progress, a number of gaps have been identified in our knowledge base, capability, and capacity that require attention.

Keywords biological introductions; marine biosecurity; invasions; non-indigenous species; management; policy

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INTRODUCTION

The introduction of organisms through human-mediated dispersal into regions where they did not exist in evolutionary and ecological time has resulted in significant ecological, economic, and social consequences (Carlton 1996, 2001; Pimentel et al. 2000; Hewitt 2003a). This issue is now considered to be one of the top threats to native biological diversity, equal to the threat posed by human-mediated global climate change (Lubchenco et al. 1991; Carlton 2001; Hewitt 2003b). Biosecurity (biological security) is the management of the risks posed by introduced species to environmental, economic, social, and cultural (including spiritual) values. Biosecurity activities generally include quarantine activities (prevention of the entry and border surveillance for pests and diseases), surveillance, short-term response, and long-term control of established pests (e.g., integrated pest management) (e.g., Parliamentary Commissioner for the Environment 2000; Biosecurity Council 2003). In addition, biosecurity responsibilities include audit and enforcement of legislation, providing sanitary and phytosanitary assurances to trading partners and may include protections against bioterrorism (Meyerson & Reaser 2002, 2003).

Aotearoa, New Zealand, lies in the southern Pacific Ocean, 2000 km east of Australia. New Zealand has the world's 4th largest Exclusive Economic Zone (EEZ) covering 2.2 million km^2 of ocean ranging over 30º of latitude—from the subtropical Kermadec Islands to subantarctic Auckland and Campbell Islands. The geographic isolation makes New Zealand reliant on sea-borne shipping for the majority (over 90% total volume) of its international commerce. Simultaneously, as an island nation, New Zealand has certain values (biodiversity, economic, social, spiritual) that are particularly at risk to biological invasions both on land and in the oceans (Ministry for the Environment 1995).

The total value of marine ecosystems (incorporating value of indigenous biodiversity and ecosysytem function) was calculated in 1994 to be NZ$184 billion per year (including fisheries) (Patterson & Cole 1999), more than twice the New Zealand Gross Domestic Product (GDP) for that year and more than half of the total biodiversity valuation (NZ$230 billion). Two-thirds of New Zealand's total biodiversity (freshwater, marine, and terrestrial) is found in the EEZ (Department of Conservation 2001). Many of these species are endemic as a result of New Zealand's 120-million-year geographic isolation from other landmasses. Endemicity ranges between 30% in the algae to over 95% in the sponges (Department of Conservation 2000; Francis & Nelson 2003). Such geographically restricted species tend to be vulnerable to the direct and indirect impacts of introduced species (Carlton 2001).

Economically, this zone produces c. 1% of the world's total fisheries catch. The New Zealand commercial catch and aquaculture production is estimated at c. 650 000 metric tonnes per year with export revenues totalling NZ$1.49 billion (US$833 million) and domestic revenues c. NZ$130 million (US$75.8 million) for the year ending December 2000 (Statistics New Zealand <http://www.stats.govt.nz> accessed 9 September 2003; SeaFIC unpubl. data).

A strong sense of connection with the marine environment is imbued in the culture of New Zealand, particularly in the indigenous Maori population (Biosecurity Council 2003). The key values associated with recreational and social use of the marine environment are difficult to quantify, yet tourism comprises c. 9% of GDP and is increasing on an annual basis. The value of the marine environment to Maori is holistic, based on spiritual and traditional aspects of Maori culture. It is virtually impossible to place monetary valuations on this component. The Treaty of Waitangi secured and guaranteed Maori rights to fisheries and other treasures. Unmanaged threats to these resources could be construed as an erosion of these rights.

Biosecurity in New Zealand is governed under the Biosecurity Act 1993 (administered by the Ministry of Agriculture and Forestry (MAF)). Biosecurity of the marine environment is delivered by a variety of groups in central and local government, however the Ministry of Fisheries has primary responsibility. Under the Biosecurity Act 1993, a Chief Technical Officer (CTO) has been appointed in the Ministry of Fisheries with responsibilities allocated by the Director General of MAF. Statutory powers allow the CTO or their approved persons to declare unwanted organisms, enter a place and inspect for unwanted organisms or risk goods, give directions to treat risk goods for unwanted organisms, and put in place area controls.

In this paper we discuss the biosecurity risks to the New Zealand marine environment and provide an outline of the current state of central government delivery with a discussion of the challenges to our meeting the expected outcomes.

CURRENT STATE OF KNOWLEDGE

Non-indigenous marine species (NIMS)

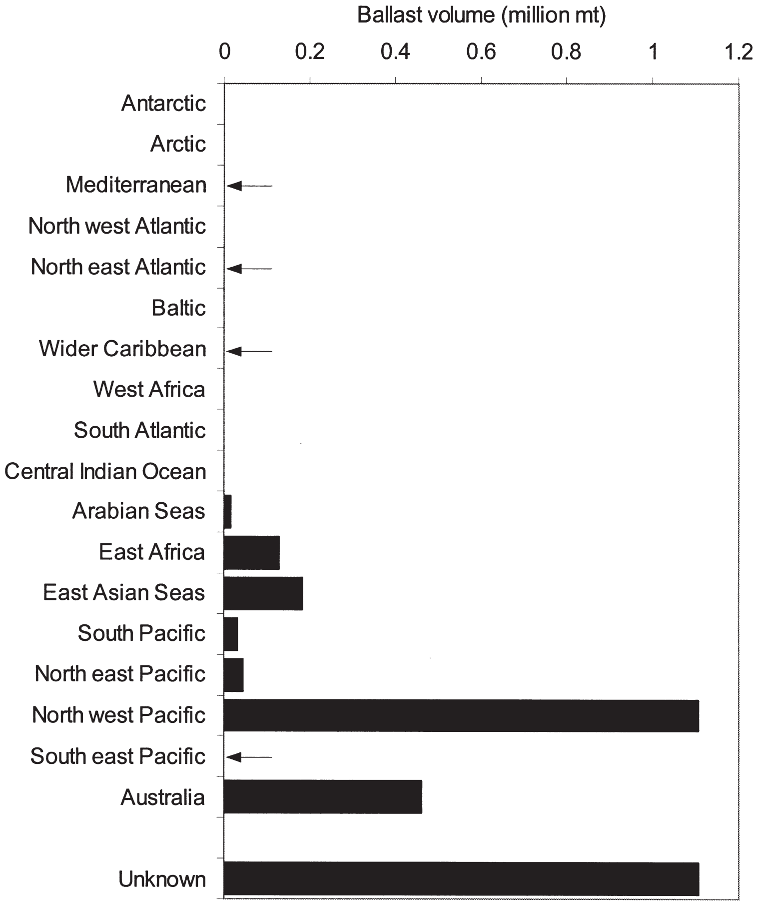
The combination of an active awareness campaign by central government and the significant value New Zealanders place on the ocean environment has led to a greater awareness of NIMS in the general population relative to other regions of the world. Over 150 NIMS have been identified in New Zealand's marine ecosystems (Gordon & Mawatari 1992; Cranfield et al. 1998; Nelson 1999). These NIMS have been detected in virtually all coastal habitat types in New Zealand, with representatives of three divisions of plants and eight phyla of animals (Cranfield et al. 1998; Nelson 1999). Many of these species present unknown risks with likely impacts difficult to identify (but see Forrest & Taylor 2003; Hewitt 2003a; Ross et al. 2003a,b).

Pathways

It is believed that Maori settled New Zealand over 1000 years ago. In all likelihood, NIMS were transported to New Zealand on the hulls of their waka (canoes). In contrast, European "discovery" and eventual settlement of New Zealand significantly expanded the opportunities for NIMS transport resulting in larger numbers of species from a wider array of ecoregions establishing successfully (Crosby 1986).

A number of pathways continue to operate in New Zealand including ballast water, hull fouling, sea-chests, and the aquarium trade (aquaculture transfers of stock and gear are considered a low international risk because of current safeguards but remain a domestic risk). Ballast water has received the most attention internationally because of links with several high profile invaders. New Zealand receives a substantial volume of ballast water relative to the size of the country from a large number of source regions (Fig. 1; see also Wotton & Hewitt 2004). The total volume for 2002 was 4.4 million mt (an increase of 11% from 2001) with all international ports of first entry receiving ballast water discharge (Wotton &

Fig. 1 Origins of ballast water discharged in New Zealand during 2002–03. Source regions are categorised according to the IUCN bioregionalisation of Kelleher et al. (1995). Volumes of less than 0.01 million mt are identified by arrows.



Hewitt 2004). Overall, the greatest volume of ballast is discharged by bulkers (2.5 million metric tonnes in 2002) and tankers (1.5 million metric tonnes in 2002).

Hull fouling has been assumed to represent an historic pathway associated with wooden vessels of the last 500 years. However, recent evidence suggests that both hull fouling and sea-chests (intake chambers in the hulls of vessels) of modern vessels present significant risks (e.g., Coutts et al. 2003; Lewis et al. 2003; Minchin & Gollasch 2003). Over 3300 international vessels arrived in New Zealand in 2002, representing a variety of hull fouling risks. The majority were commercial merchant vessels (2581) operating at high speeds with good maintenance schedules minimising external hull fouling risks, however sea-chests and internal piping may harbour communities (Coutts et al. 2003). An additional 794 vessels were categorised as recreational yachts whose maintenance schedules vary significantly (Floerl & Inglis unpubl. data). As has been demonstrated in New Zealand (Hay & Dodgshun 1997; James & Hayden 2000; Floerl & Inglis unpubl. data) and elsewhere (Darwin, Australia—Bax 1999; Willan et al. 2000; Cairns, Australia—K. Niel pers. comm.), the hull fouling on these vessels poses a current risk to the integrity of marine communities. Hull fouling inspection regimes do not exist in any nation; this gap has been identified as a significant unmanaged risk internationally (Minchin & Gollasch 2003) and in New Zealand.

CURRENT STATE OF MARINE BIOSECURITY DELIVERY

The Ministry of Fisheries has had a Marine Biosecurity Team since 1998. In this short time, significant progress has been made in identifying the delivery requirements, developing prioritisation frameworks, and establishing research projects to underpin the development of policy and response capability.

Risk management framework

The lack of knowledge, limited capacity, and low funding has required a pragmatic approach to developing policy and management options. The Ministry undertook the development of a Risk Management Framework (RMF) to evaluate the critical system risks to biosecurity delivery as a mechanism for prioritisation (Cox unpubl. data). This RMF focuses on managing biosecurity risks to four core values: Healthy Environment, Strong Communities, Vibrant Commerce, and High Quality Recreation.

Pre-border management

Current activities in pre-border management include a ballast water Import Health Standard, which requires mid-ocean ballast water exchange and no discharge of un-exchanged waters from any country unless exempted on the grounds of safety. No discharges of un-exchanged water sourced from Tasmania and Port Phillip Bay, Victoria, Australia are permitted (i.e., no exemptions). This unilateral action was one of the first globally (Hewitt 2003b). New Zealand also actively participates in the International Maritime Organisation (IMO) Marine Environmental Protection Committee (MEPC) in the development of International Convention for the Control and Management of Ship's Ballast Water and Sediments (adopted 13 February 2004; see: http://www.imo.org>, accessed 8 March 2004).

The Ministry has contracted research to determine the risk profile of species likely to be transferred to New Zealand (associated with shipping) based on current trading activities. This project (conducted by Sinclair Knight Merz) has provided a first move towards risk profiling in the New Zealand context using similar methodologies as Ricciardi & Rasmussen (1998) and Hayes & Sliwa (2003). Next steps include determining likely impacts on the core values in the RMF for each potential invader.

Our ability to discern and prioritise management based on relative risks of the primary pathways (ballast water, hull fouling, aquaculture) for domestic and international transfers has been recognised as a significant gap in our understanding. The need to undertake preliminary evaluations in a consistent fashion (e.g., Jones & Hayden 2000) must be coupled with management outcomes to provide biosecurity delivery. In the meantime, mechanisms and tools (including risk assessment) for pre-border management of hull fouling are progressing in international fora (e.g., IMO GloBallast Risk Assessment Workshop 2003).

Border management

Marine borders are difficult to manage; no clear boundary exists before physical arrival in port. Organisms living on a vessel's hull can potentially spawn while transiting coastal waters up to the point of berthing in port (before inspection). Over 20 active marine pathways have been identified in New Zealand (Table 1). However, two are considered to pose the most serious threat: ballast water and hull fouling of merchant and recreational vessels.

As discussed above, merchant vessels are required to exchange ballast at sea (outside the NZ EEZ) and provide details to MAF Quarantine Service inspectors for evaluation of ballast water management for each ship visit to New Zealand. MAF Quarantine Service inspectors give permission for ballast water discharge on the basis of this information.

As elsewhere in the world, our ability to manage hull fouling at the border is limited to the tools at hand. Pre-border management and education to maintain clean hulls will always be the best option. Hull fouling is not currently inspected at the border. However, border officers collect information that is being used to determine risk. The Ministry is developing standards for facilities to treat fouled vessels and a suite of guidelines and tools to increase awareness of the need to remove hull fouling before travelling to another region. Simultaneously, border and valued area management options are being developed. Additional work is being undertaken by various research providers to determine the relative risks between categories of vessels.

These border risks are increasing quickly; over the past 4 years merchant vessel visits have increased by 10% per annum with an associated increase in ballast water discharge. Simultaneously, changing patterns of trade are exposing New Zealand to additional species not previously capable of reaching New Zealand (Taylor et al. 2000). Similarly, the growth of internet based mail-order for the aquarium trade has resulted in a proliferation of available species, some of which pose significant threats to our marine environment (e.g., *Caulerpa taxifolia*).

Post-border management

Our current state of knowledge of NIMS in New Zealand has been derived in an ad hoc fashion, harvesting information from museums, published literature, and anecdotal collection. New Zealand has embarked on a series of central government funded baseline evaluations of high risk entry points to determine the current scale of introductions (Wotton & Hewitt 2004) using internationally accepted protocols (Hewitt & Martin 2001). The baseline surveys are being completed by NIWA under contract to the Ministry in 13 ports and three marinas with re-surveys scheduled after 3 years. These re-surveys will allow an evaluation of the current rate

Table 1 List of international and domestic pathways of relevance to New Zealand (based on Carlton 2001; ICES Code of Practice).

Category	Pathway
Ships	Ballast water and sediments
	Hull fouling
Moveable structures	Solid ballast
(Oil platforms, barges, dredgers, floating docks)	
	Hull fouling
	Ballast water and sediments
Other craft	Hull projections and cavities
(Merchant, fishing, and recreational/leisure)	(sea-chests, thrusters, and internal piping)
	Hull boring
	Aquatic cargo (wells and tanks)
	Anchor/anchor chains/lockers/moorings
	Scuppers and bulwarks
	Small craft trailers
	Dredging spoil
Aquaculture fisheries	Intentional release and stock movements
	Accidental release
	Gear movement
	Discarded nets, floats, traps
	Discarded packaging materials
	Discharge of feeds (live, fresh, and frozen)
	Release of transgenic and GMO species
Wild fisheries	Stock movement
	Population re-establishment
	Processing of live, fresh, and frozen products
	Live bait movement
	Gear and transport media (water) movement
	Discarded/lost fishing gear
	Discard of target and non-target species (bycatch)
	Live trade for consumption: accidental/intentional release
Aquarium industry and public aquaria	Intentional release
	Accidental release
	Untreated aquarium and waste discharge
	Living food movement
Marine leisure tourism	Live bait movement
	Accidental/intentional transport and release of fishing catch
	Diving gear movement
	Fishing gear (including boots) movement
Research and education	Intentional release
	Accidental release
	Water and waste discharges
	Living food movement
	Diving gear movement
	Field and experimental gear movement
	Restoration, mitigation and rehabilitation
Other	Alteration of water courses and flow regimes
	Irrigation canals (including saline ponds)
	Municipal and other waste/water treatment discharges

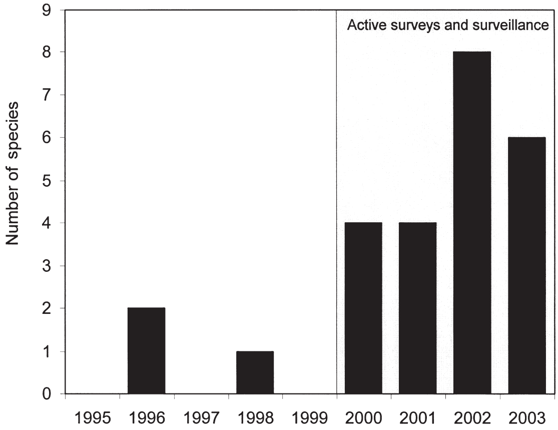


Fig. 2 Detected incursions of New Zealand's marine environment, based on dates of first record (or dates of collection from an isolated and previously believed uninfected locality) and period of active surveys and surveillance activities.

of invasions and help identify further surveillance needs (see Hewitt & Martin 2001).

Additionally, a surveillance regime in high-risk entry points has been established for early detection of incursions of a suite of six notifiable organisms (Wotton & Hewitt 2004). Detection capabilities are being evaluated, specifically for the listed notifiable organisms. As a result of increased awareness and observation, the rate of detections and reporting activities has significantly increased since 2000 (Fig. 2).

Incursion response activities are guided by a standard protocol, which has been developed to provide a clear and transparent decision-making process. The core values of the RMF establish the context for incursion response risk assessment guidelines, based on New Zealand risk management standards (Standards New Zealand 1999, 2000). Incursion response is closely linked to surveillance activity, with response plans being prepared for the six notifiable organisms (Wotton & Hewitt 2004).

The management of domestic translocation pathways has been identified as a high priority to prevent the movements of NIMS already in New Zealand. High-risk movements of vessels and aquaculture gear pose a significant threat to several "high-value" areas. A voluntary Code of Practice for hull cleaning has been developed and implemented for vessels trading with the subantarctic and Chatham Islands.

A focal challenge to the development of a marine biosecurity capability has been the post-border management of the Japanese kelp, *Undaria pinnatifida*. Several lessons have been learned through the management of this species. Tools for response, domestic pathway management, and control measures have been developed. These have helped to identify gaps, as discussed below.

CHALLENGES

The marine environment is a new focus for biosecurity in New Zealand. As illustrated above, significant measures are in place and solid progress has been made to date to manage risks posed to the marine environment. However, in pursuing our goal of a comprehensive, end-to-end regime for marine biosecurity, further steps are needed. The challenges identified in the Biosecurity Strategy (Biosecurity Council 2003) relate to knowledge, capability, and capacity. Here, we discuss some critical gaps, though many others exist.

Knowledge

Our knowledge base for marine invasions is poor (Carlton 1996; Ruiz & Hewitt 2002; Hewitt 2003b) and we currently do not have a clear understanding of the number (and identity) of marine invasions in New Zealand coastal waters outside of specific high-risk entry points. This is being rectified with current research projects. However, the baseline evaluations should be extended to those areas subject to high impact risks (rather than solely high incursion threats). Similarly, we have only a rudimentary ability to predict which species are likely to be transported to New Zealand, and determine whether they pose a significant threat to the core values identified in the RMF. Our knowledge of existing pathways for marine species to enter, or be moved around within, New Zealand, and the relative risks posed by these pathways, requires additional research and evaluation.

One challenge to central government is to identify such research needs, both for pathways into and within New Zealand. Increasing our knowledge base will not solely service biosecurity, but will also aid our understanding of and obligations to biodiversity, fisheries management, and other outcomes.

Capability

Our capability to manage pre-border risks (e.g., ballast water and hull fouling associated with international shipping, fishing vessels, and hull fouling of recreational yachts) is restricted to available technologies and regulatory arrangements. The development of an international instrument to manage the risks of ballast water (International Convention for the Control and Management of Ship's Ballast Water and Sediments; see also Hewitt 2003b; McConnell 2003) will greatly increase our responsibility, yet the capability to monitor and regulate this instrument once adopted by New Zealand will need to be established. The issues associated with hull fouling are more problematic and will require tremendous effort to identify the most appropriate mechanisms to achieve management outcomes. As discussed previously, numerous voluntary regimes have been explored as short-term solutions, yet the growing realisation that the ban on tri-butyltin (TBT) antifouling paints (International Convention on the Control of Harmful Anti-fouling Systems on Ships, adopted 5 October 2001; <http://www.imo.org> accessed 9 September 2003) will have downstream impacts on hull fouling associated invasions indicates that new solutions to old problems need to be developed.

Our capability to detect species both at the border (interception) and post-border (surveillance) is significantly restricted. Few tools for rapid detection and unequivocal identification are available. Those that do exist rely heavily on taxonomic expertise. This taxonomic capability is limited in many marine groups. Tools are being developed to increase our ability to evaluate management activity (e.g., ballast exchange) or to detect individual species using molecular (Deagle et al. 2003) or biochemical techniques. However, these require significant research and development funding. There is no Crown funded National Centre explicitly for the rapid diagnosis of marine organisms, unlike the terrestrial biosecurity National Centre for Disease Investigation. As such, we rely on capacity to be maintained in museums, universities, and research institutions without explicit funding arrangements to meet this critical role. Without explicit support for this capability, New Zealand will continue to be at risk of the continued loss of taxonomic skills because of an aging population with little replenishment (Dayton 2003).

Lastly, the tools are limited for treating pathways and undertaking eradication or control campaigns in the marine environment. For example, ballast water treatment systems and methods are being developed and tested in New Zealand and abroad; non-TBT hull fouling treatment systems are being tested; and verification tools for ballast water exchange are being evaluated for practical implementation under bilateral agreements with various nations.

Globally, very few detected marine incursions have resulted in response actions and, of those, a limited number have succeeded in eliminating the introduced population. In all instances, these eradication and control attempts have been undertaken using either physical (e.g., diver removal, heat treatment, burial) or chemical (e.g., chlorine, rotenone) techniques in restricted areas (e.g., Culver & Kuris 2000; Secord 2003; Hewitt et al. in press). Recent reviews of available techniques have been undertaken (e.g., McEnnulty et al. 2002), yet these techniques require development and field-testing to determine efficacy and collateral impact. Bax et al. (2003) discuss the procedures that should be considered to undertake a response action. This framework is loosely correlated with the approach adopted in the Ministry of Fisheries (see Wotton & Hewitt 2004).

Capacity

New Zealand's marine environment is highly valued in environmental, economic, spiritual, and social contexts. The NZ EEZ represents 22 times the landmass, and c. 5% of primary productivity GDP, yet current biosecurity investment in the marine sector is less than 1.5% of central government's total biosecurity expenditure. As a consequence, the capacity to deliver biosecurity outcomes is severely hampered. Increasing marine biosecurity capacity is recognised as a priority in the Biosecurity Strategy (Biosecurity Council 2003) with core capacity building required to develop policy, regulate and manage pre-border, border, and post-border activities.

Multiple research providers undertake marine biosecurity research activities (e.g., Forrest et al. 2000; Hayden & Whyte 2003). These activities, however, are currently uncoordinated (Hayden 2000), with funding provided by multiple central government agencies (e.g., Ministry of Fisheries, Department of Conservation, Foundation for Research, Science and Technology, Ministry for the Environment). The need for a coordinated funding strategy, with clear leadership roles, is crucial to guaranteeing scientifically sound biosecurity outcomes in the marine environment (Biosecurity Council 2003).

CONCLUSIONS

The Ministry of Fisheries leads the delivery of marine biosecurity in New Zealand with significant effort from other local, regional and central government bodies. The Ministry has taken a pragmatic approach to prioritising activity, relying on a Risk Management Framework to highlight the most pressing issues. In the short time the Marine Biosecurity Team has been established, great gains have been made in developing frameworks and policies to deliver biosecurity outcomes. Research has been prioritised to provide input into policy and management, and specific gaps have been identified that require additional action. Despite the relative immaturity of marine biosecurity efforts in New Zealand, our system is identified globally as one of the most innovative, comprehensive, and advanced.

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ADDENDUM

As part of the Biosecurity Strategy Implementation, the Ministry of Agriculture and Forestry has been identified as the lead agency for biosecurity delivery in central government, and marine biosecurity functions have been transferred from the Ministry of Fisheries.